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research trends

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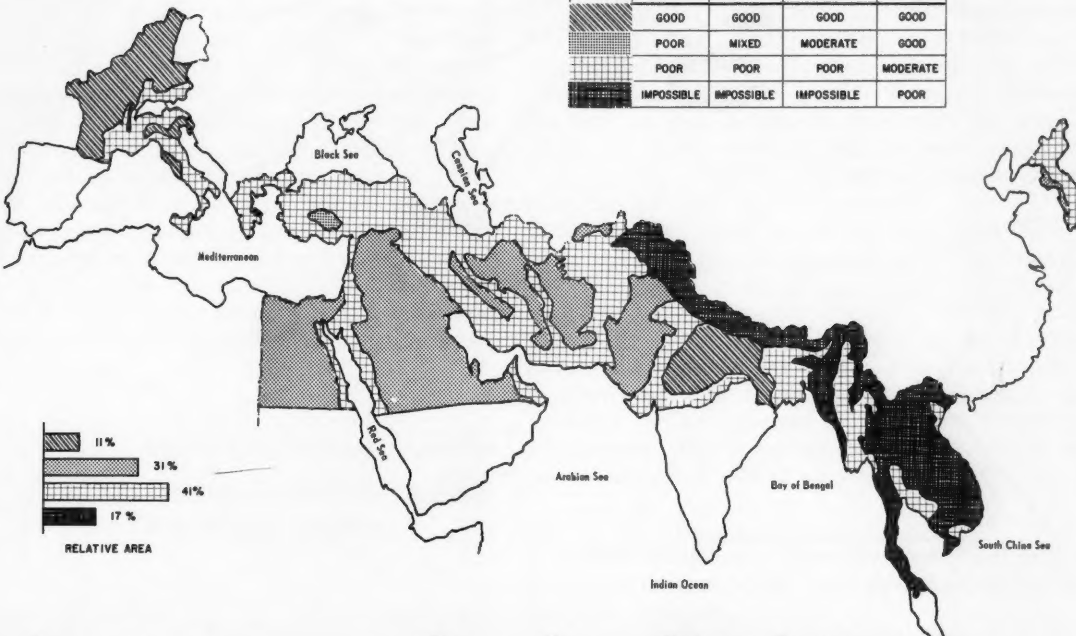
AREA	SUITABILITY FOR OPERATIONS OF FORCE TYPE- HEAVY, ROAD & RAIL	HEAVY, CROSS-COUNTRY	LIGHT, CONVENTIONAL AIR	LIGHT, VTO/STO AIR
(diagonal hatching)	GOOD	GOOD	GOOD	GOOD
(fine stipple)	POOR	MIXED	MODERATE	GOOD
(grid)	POOR	POOR	POOR	MODERATE
(dark)	IMPOSSIBLE	IMPOSSIBLE	IMPOSSIBLE	POOR



Aircraft and Combat Mobility...

by MURRAY E. KAMRASS

MODERN armies, for all their sophisticated impedimenta, such as effective weapons, target-locating devices and advanced communications systems, may be even less mobile than the Roman legions.

General Lyman L. Lemnitzer, Chairman of the Joint Chiefs of Staff, recently commented on mobility:

"Throughout history, a major limitation on the freedom of action of land forces — and, consequently, on their effectiveness — has been the barrier of terrain. We can now foresee a time when mountains and rivers and other terrain features will cease to be obstacles or limitations. They will be meaningful chiefly as advantages to be exploited as the situation indicates."

This view of future mobility stems from the expected capabilities of future aircraft which could be integrated into the army's combat organizations.

Army aircraft are currently used for reconnoitering, liaison, limited resupply, evacuating wounded and moving light forces. Such uses, however, are only supplemental combat tasks. Overall mobility of the army cannot be significantly increased unless additional mobility is given to the preponderance of army forces which are relatively slow and dependent upon favorable terrain. Heavy firepower is especially hampered by these restrictions.

How can air vehicles in future operations provide an important increase in mobility, and how can we extend their use beyond mere supplementary functions by combining them appropriately with other military equipment? Airborne systems are likely to be expensive to buy and support but in vast undeveloped regions such as Southeast Asia they are apt to be the only means by which heavy firepower can be delivered. Such systems would also be useful for assisting the ground forces in areas where ground movement is relatively easy. This article discusses the need for mobility and shows how aerial weapons systems can help to achieve it.*

Requirements More Demanding

Military environments in which U.S. forces might become involved range from a large nuclear conflict

*Views expressed herein are those of the author and do not necessarily represent those of the military.

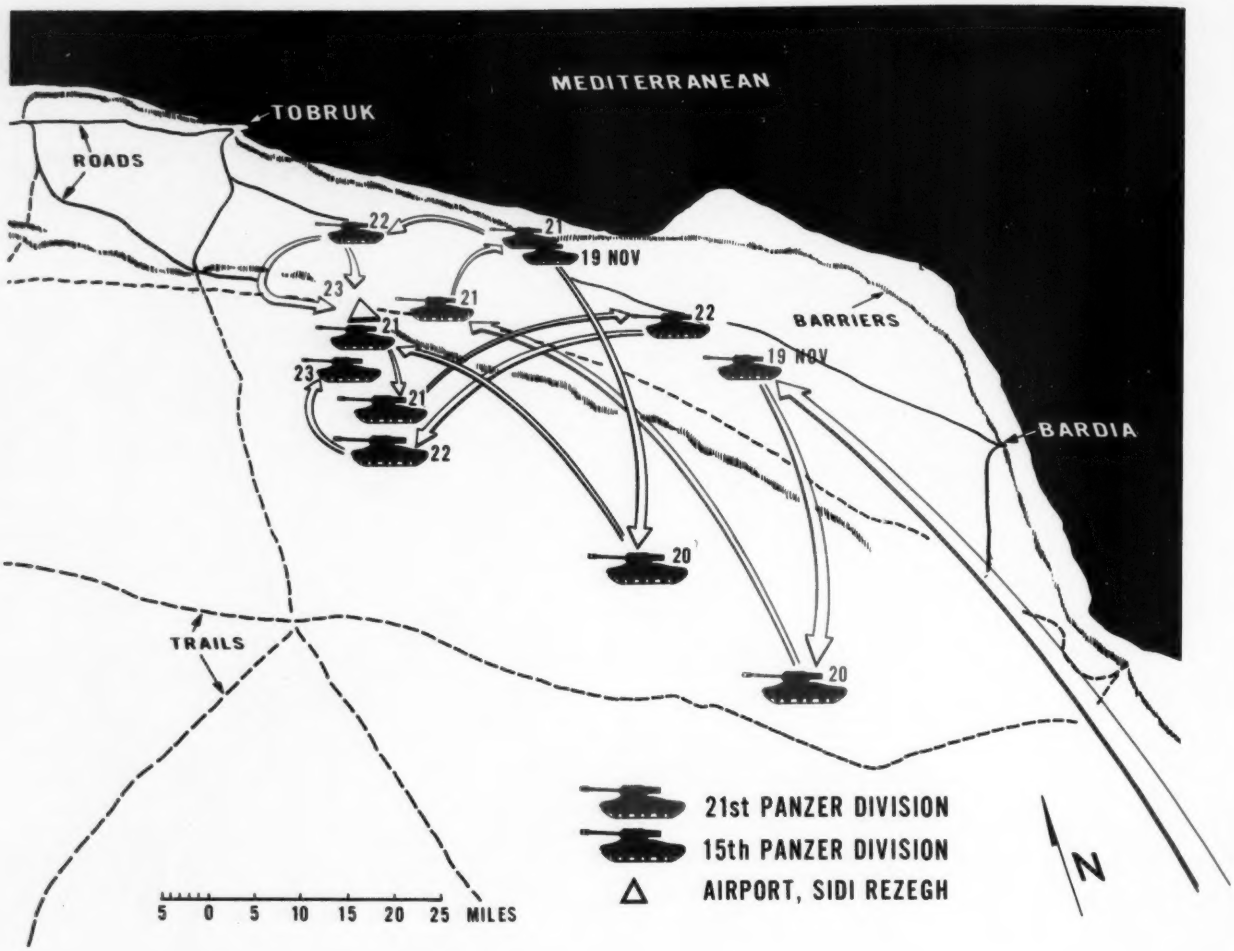


FIG. 2 — **Crusader Battle, Panzer Division Movements, November 19-23, 1941.**

to a small show of force. The Army should be prepared to conduct operations at any point in this set of environments. High mobility is desirable in virtually all of these potential situations. Moreover, the degree of mobility needed is continually increasing.

In the "Crusader" battle of 1941 fought in the Libyan desert, Rommel's outnumbered Afrika Korps defeated a British force under Auchinleck.[1, 2] A five-day battle involved several long movements of large military units. Figure 2 shows the movements of two Panzer Divisions during the battle. (Many other units, both British and German, were involved, but are eliminated from the chart for clarity). German forces moved much faster than is usual for armored units. For example, the 15th Panzer Division reversed itself completely within 24 hours, traveling 25 miles or more on each leg of the trip. The 21st Panzer Division made a 25-mile march in 2 hours. A vital struggle of the battle was for the British airfield ultimately captured by the Germans. Rapid maneuver was the key to German victory.

French Army action in Algeria is a modern example of mobile combat. Helicopter-borne assault forces were used to break up rebel bands sighted by reconnaissance aircraft. For 50% assurance of successful assault on the rebels, four hours was the maximum troop movement time allowable after sighting. Since nearly all the engagements required traveling beyond 40 n. mi. through rugged mountain terrain, air transport was the only way to achieve reasonable success.

Data from these two situations are illustrated in the mission matrix (Figure 3) which represents mission requirements expressed in time and distance. In the Crusader battle, the highest average speed of any move was 12.5 miles per hour. In Algeria, the lowest acceptable average speed (including delay time) for 50 percent effectiveness was 11.5 mph; the highest speed required for the same effectiveness was 45 mph.

In future land combat environments, nuclear and new non-nuclear weapons will provide tremendous capability for destruction of military forces and installations. Advanced target location methods will permit accurate aiming of these weapons.* Operations will tend toward greater rapidity and frequency of movement, making maximum use of dispersal and terrain masking.

In offensive missions only minutes may be available for moving 100 miles or more. Defensive movements may have to be performed in seconds.

*See "The Problem of Combat Surveillance", Nye, Herbert A., Research Trends, Vol. VII, No. 3, Fall 1959.

In terms of mobility, then, the trend is for longer distance missions conducted in shorter time.

Geography Affects Mobility

What are the geographical characteristics affecting mobility?[3] On page 1 is a map of the general area peripheral to the Soviet-Chinese mainland. This area, of some 4.3 million square miles, contains virtually every kind of terrain and climate in the world except that of arctic regions. Various regional characteristics which affect military movement are shown on the map.

In Western Europe rapid movement of different types of forces is aided by relatively favorable terrain and a multiplicity of roads and railroads. In vast areas of Asia and Africa, on the other hand, only cross-country movement is possible (there are few roads and railroads), and in many areas, even cross-country movement is extremely difficult. However, 85 to 90 percent of the area is suitable for the operation of VTOL aircraft. The other 10-15 percent includes such areas as the mountainous jungles of Southeast Asia, where the operation of even VTOL aircraft is difficult. To a lesser degree, areas suitable for VTOL/helicopter operations also are suitable for aircraft requiring short landing strips of 1000-1500 feet.

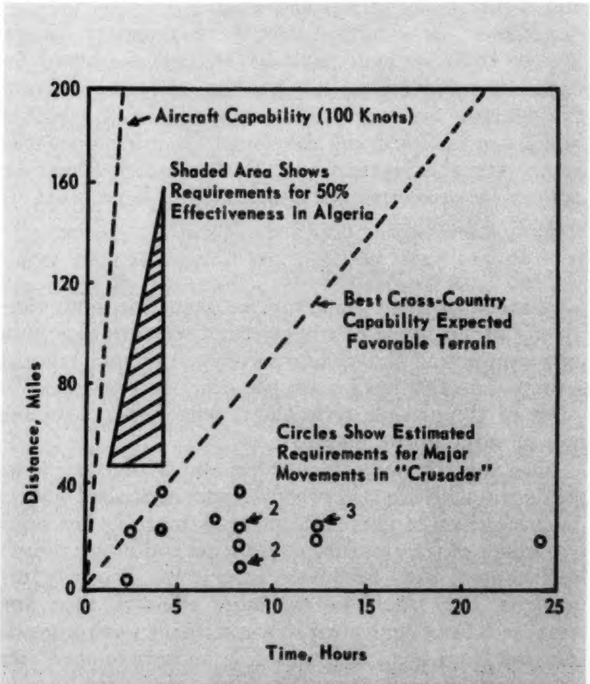


FIG. 3 — Mission Matrix — Operation Crusader, Algeria.

The ground vehicle capability for the future will show improvements in efficiency and in ability to negotiate difficult terrain. Nevertheless, cross-country speeds will be no higher than before and road speeds sometimes lower. These improvements will not provide the Army with significantly increased mobility or freedom of tactical action in most of the geographical areas shown on the map.

Airborne Weapons Extend Capability

We have seen that future military environments will require more mobility and that potential ground mobility will often be inadequate, particularly in vast undeveloped areas of the world. Since heavy firepower limits the mobility of land forces, we are led to consider aircraft as vehicles for such firepower.

Airborne systems appear capable of performing a wide variety of weapons delivery tasks, including some which cannot be performed by ground-based systems. For example, the strike of moving vehicles can be accomplished only by a system maintaining sensory contact with the target until a weapon is delivered. Similarly, mobile missile batteries must be attacked within the short time available between sensing and their moving. Aircraft also provide mobile elevated platforms for close support firepower.

On the other hand, air defense capabilities have increased, making aircraft extremely vulnerable to ground fire. The ability to survive and the ability to deliver effective fire against ground targets interact: as the aircraft flies lower, it loses its ability to detect ground targets and to deliver fire accurately against them while it gains protection against enemy air defenses. Survivability can be increased by flight and weapon delivery tactics, electronic countermeasures, decoys and combined air and ground activity.

Elements of Airborne Systems

Major elements of an airborne weapons system are the aircraft, its weapons, and target acquisition and fire control devices.

Aircraft should be able to operate from unprepared areas and, in order to be most responsive, should be based with the troops they are supporting. Thus, short or vertical take-off aircraft with low support needs are essential.

Helicopters are now the only proven operational vertical take-off aircraft. Compound (unloaded rotor) aircraft offer improvement over helicopter range, speed and maintenance requirements and seem to be well adapted for military transport missions under 350-400 n.mi. radius. Various other VTOL concepts with potential applicability include tilt wing, tilt rotors, ducted fans, lift fans, deflected slip-stream and several variants and combinations of those configurations. These concepts offer additional speed and range over rotary wing aircraft.*

Future VTOL machines, because they could land almost anywhere and because they could carry the weapons and target acquisition systems required for accurate weapon delivery might be the basic vehicles for delivering heavy firepower in mobile operations.

Acquiring Targets

Acquiring targets involves detection, identification, location and aiming. Equipment for accomplishing

*"Airplanes . . . Straight Up", Vidal, Robert J., Research Trends, Vol. VIII, No. 2, Summer 1960.

these tasks ranges from the human eye and brain to sophisticated radiation sensors, computing devices and displays. Selection of target acquisition systems depends on weapons and aircraft to be used, tactics to be employed, targets to be attacked and such special capabilities as adverse weather operation. A package of several sensors will be useful, each supplementing the others in target detection and identification. Such

Type	Major System Comp.	Missions	Weapon Guidance	Weapon Launch	Comp. Payload lbs.
Missile Launch A/C	Target Loc. Fire Control IFF Weapons	Close Supp. Fire Supp. Recce. Strike (Mov. Targets)	Flat or Ballistic	Air Air, Grd Air, Grd	3700 (Incl. 6 Missiles)
Target Sensing A/C	Target Loc. Data Link IFF	Fire Supp. Recce. Strike	Ballistic	Grd.	1400
Target Sensing A/C + Drone	Target Loc. Fire Control Data Link IFF	Fire Supp. Recce. Strike (Mov. Targets)	Flat or Ballistic	Air	1400

FIG. 4 — **Several Manned Aircraft Combat Systems.**

sensors are already in existence, but further development is needed to improve sensitivity and to provide meaningful displays.

Advances in Weaponry

Although the over-all art of weaponry advanced considerably in the last decade, air-to-ground weapons development failed to share in this advance.

Integration of weapons and aircraft requires consideration of the mission, target and environment as well as the characteristics of the weapons. A guided weapon, for example, using a line-of-sight or homing mode is essential for striking a hard, small target effectively at safe range. Area suppressive fire, however, can be delivered by unguided weapons, although present weapons are not especially suitable for continuous suppression. New warhead development and integration with weapons and weapon delivery tactics could provide great improvement.

But air-to-ground weapons are only one way to attack targets. Aircraft acting as the eyes of ground-fired weapons can increase their effectiveness. While this is not a new role for aircraft, the ranges of new weapons and their potential for guidance can change the manner and scope of employing them. Additionally, the aircraft might be used to transport integrally mounted ground-fired weapons, thus eliminating the weight of wheels, axles and special chassis which must be transported to and about the battlefield.

Tomorrow's Systems

Several types of aircraft fire-delivery systems can be described in accordance with the concepts discussed, with an estimation of the general aircraft requirements they generate (Fig. 4). The relative costs of these methods of fire delivery would depend on the situation.

One type would consist of a V/STOL aircraft carrying target locating and fire-control equipment as well as its weapons. Such weapons could be designed to provide either ballistic or flat trajectories. Aircraft requirements of the system might include a radius of 100-200 miles, speed of about 0.75-0.90 Mach number at low altitude, and the ability to avoid terrain in any weather. Its weapons might be launched from the air or while the aircraft is resting on the ground.

Another possible system would enable the aircraft to call for fire from the rear. Such a system would include equipment for detecting and transmitting target information to a remote launching site. Smaller aircraft and a better selection of warheads are primary advantages of this system over the previous one.

A third possible system might require a team of two aircraft. One would carry and operate the target location and guidance equipment; the other would be the weapon vehicle. Weapons might be either air-launched or ground-launched. Advantages of this system over the one above are a faster response time and the ability to strike moving targets. A drone or the missile itself could serve as the weapons aircraft.

These basic systems with various modifications could be useful for many missions, including strike, close support, and suppressive fire. The choice of weapons would allow extension of the support role to much greater distances and to many targets outside the scope of present systems, such as moving vehicles, rapidly emplaced and launched missiles, troop concentrations, and momentarily parked aircraft.

Although development would be necessary before any of these systems could be realized, it should be noted that they represent a synthesis of reconnaissance, fire delivery, fire control and transportation capabilities which are already being developed for other purposes. Integrating these factors into effective mobile firepower systems is necessary, but much of the basic work is already complete.

Tactics Must be Revised

Weapons systems should not be devised without considering their mode of employment. Hardware is only one component of a military combat system. Human beings and organization are the other components. In view of the possible technology, what other advances can be made in the system?

Consider the potential combat ability of small units equipped with the airborne weapons described above. Such units could move 100 miles or more in one hour regardless of terrain; they could sense and locate targets and control high firepower accurately. Properly organized, they could be far more effective than any current unit of equivalent size in military environments ranging from small scale action in an undeveloped area to major war in Europe. The basic technology already exists for such systems; so apparently does the requirement.

REFERENCES:

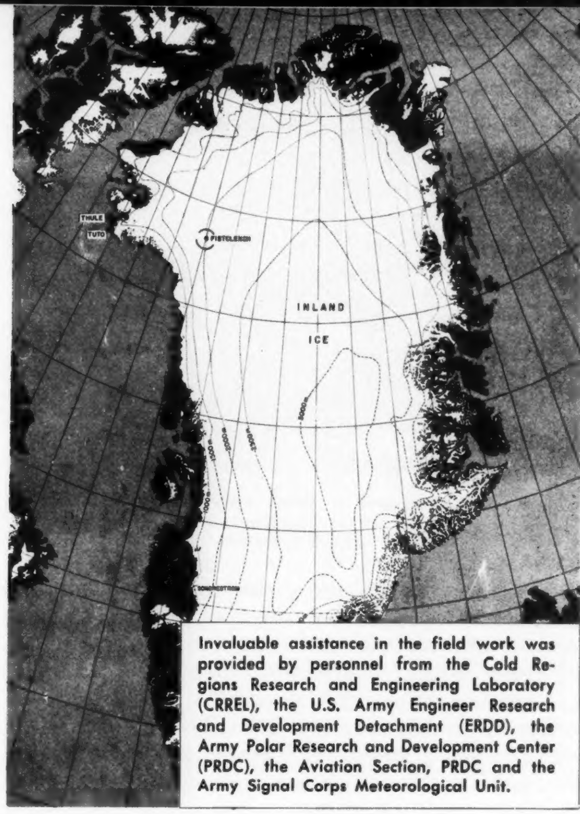
[1]Patton, Capt. George S. "Operation Crusader". ARMOR, May-June, 1958.

[2]Churchill, Winston S. "The Grand Alliance". Houghton Mifflin Co., 1950.

[3]Deitchman, S. J. "Classification and Quantitative Description of Large Geographic Areas to Define Transport System Requirements", 28 December 1959, Presented at AAAS in Chicago.

Seeding Whiteouts in Greenland

by JAMES E. JIUSTO and RODDY R. ROGERS



Invaluable assistance in the field work was provided by personnel from the Cold Regions Research and Engineering Laboratory (CRREL), the U.S. Army Engineer Research and Development Detachment (ERDD), the Army Polar Research and Development Center (PRDC), the Aviation Section, PRDC and the Army Signal Corps Meteorological Unit.

FIG. 1 — Greenland.

Some of the world's most difficult navigation problems are faced by arctic travelers as they try to find their way through snow, fog, and low overcast clouds. The snow-covered terrain is responsible for much of the difficulty because it has the same brightness as the overcast.

The problem is most critical over uniformly flat terrain, such as the Greenland ice cap, where there are few shadows to assist in orientation. Under meteorological conditions of low clouds or poor visibility, it is not uncommon to be surrounded by a uniformly bright whiteness with no visual references. This phenomenon, particularly dangerous for fliers, is termed a *whiteout*.

A preliminary survey to observe whiteouts and their characteristics was made in northwestern Greenland during the summer of 1959 by members of the Laboratory's Atmospheric Physics Section. At the same time a climatological study of the area was made to estimate the percentage of whiteouts caused by fogs and stratus clouds of liquid water drops at subfreezing temperature. These so-called supercooled clouds are especially suited to dissipation by seeding with dry ice.

The survey, supported by the Army Office of Ordnance Research,* disclosed that during summer, whiteouts over the ice cap are generally associated with supercooled clouds. Along the coastline warmer-than-freezing clouds are more typical. Thus effective weather modification techniques have to include seeding materials applicable to both supercooled and "warm" cloud conditions.

Experiments Supported by U.S. Army

An experimental program was undertaken by the Laboratory in the summer of 1960 under sponsorship of the U.S. Army Cold Regions Research and Engineering Laboratory to determine the extent to which Greenland whiteouts and low clouds could be modified. Program objectives include establishing a capability for maintaining safe landing corridors at fixed ice cap installations; equipping aircraft with appropriate seeding apparatus for executing safe descents when unexpected supercooled whiteouts are encountered; and conducting uninterrupted ground transportation and strategic maneuvers during marginal weather conditions.

*Now Army Research Office — Durham.

Principles Explained

Cloud modification experiments and related cloud physics investigations have been conducted by Cornell Aeronautical Laboratory for several years. Previous small-scale experiments in the Buffalo area, as well as investigations by other organizations, demonstrated that modest amounts of dry ice, when dropped into relatively thin, stable layers of supercooled clouds, induce snowfall and subsequent clearing in the seeded area.

The precipitation mechanism involved is the classical Bergeron-Findeisen ice-crystal process. As pebble-size particles of dry ice fall through a cloud of supercooled water droplets, cloud modification begins. The dry ice has a temperature of approximately minus 78°C. — and by cooling its immediate environment to very low temperatures leaves a swath of minute ice crystals in its wake. The difference in saturation vapor pressure between water and ice makes the ice crystals then grow at the expense of the evaporating water drops.

As the process continues, the ice crystals approach fallout size, while the amount of liquid water diminishes. Snowfall results, and if turbulent mixing does not bring excessive quantities of moist air from surrounding parts of the cloud into the seeded area, clearing will take place.

Dry ice will not cause important changes in clouds in which ice crystals are already present, or in clouds that are warmer than the freezing temperature. Two of the agents considered for warm cloud modification

FIG. 2 — **Hole appears in clouds after seeding with dry ice. Upper right is wing of de Havilland Otter aircraft used for seeding operation.**

are hygroscopic salts and carbon black. Hygroscopic salts serve as a sink for water vapor; carbon black absorbs solar radiation and acts as a heat source. Each of these processes, therefore, should have the effect of lowering the relative humidity in the cloud. Theoretically, if the air is dried sufficiently, the cloud particles will evaporate and significant clearing should result.

Clouds and Fog Seeded

Field experiments on Project Whiteout were conducted in Greenland from 21 June to 14 August 1960, a period during which the sun remains above the horizon at that latitude (76°N). Major emphasis was placed on whiteout seeding operations over the ice cap. The first six weeks were devoted to experiments with supercooled clouds and fog in the vicinity of Camp Fistclench, situated 220 miles inland on the ice cap at an altitude of 6850 feet (Fig. 1). During the remaining time the base of operations for investigating warm clouds was Camp Tuto, located 15 miles from the coast at the foot of the glacier.

At Fistclench, an Army research outpost, living quarters for the 100-to 200-man community were located in ice tunnels below the surface of the glacier. Jamesway huts, the standard housing units, are essentially canvas and wood structures shaped like quonset huts and heated with oil stoves. Above "ground", the endless expanse of white ice cap and dust-free atmosphere presented a variety of arresting sights, shifting with solar position and weather conditions. Travel to and from nearby field stations was accomplished with caterpillar-tread vehicles called "Weasels". Such movement was confined to well-marked routes to avoid wandering away from the only reference landmarks on the polar plane.

The first task consisted of converting a military trailer or "wannigan" to a field laboratory and staking out a test area. In this remote area where facilities and tools are sorely limited, seemingly simple tasks can become extensive operations. But within three days the last preparations were made and field experimentation awaited only the cooperation of the weather.

Several seeding agents, including dry ice, liquid carbon dioxide, silver iodide, carbon black, and hygroscopic salts, were eventually dispersed into clouds or fog by means of a de Havilland Otter aircraft, a Sikorsky H-34 helicopter, a tethered 1200 cubic foot blimp, and small rockets.

Dry Ice Dispensed

Dry ice was crushed to chunk sizes less than one inch in diameter and released in flight while the aircraft flew 50 to 100 feet above the clouds. Of the eight tests in which dry ice was dispensed from the Otter, six led to successful cloud dissipation and visibility improvements. Several times it was possible to descend through holes created by the seeding and to land without hazard.

A striking progression of events followed the seeding: The supercooled water cloud began to crystalize immediately. Within 5 to 10 minutes, the seeded track could be distinguished by its darker texture and the appearance of sun dogs, sun pillars, and halos (Fig. 2). These optical phenomena occur only in the presence of ice crystals. Snow began to reach the ground from the seeded cloud in 15 to 20 minutes. Clearing began in 25 to 30 minutes (Fig. 3).

Samples of the cloud particles were collected during each seeding trial on microscope slides coated with a thin layer of gelatin. Characteristic two-dimensional replicas, resulting from absorption of water droplets or melted ice crystals by the gelatin film, made it possible to determine particle phase (water or ice) and size. In collecting airborne samples, the slide was held outside the airplane window, gelatin side forward, for about one second. Round or elliptical replicas indicated water droplets, while angular shapes denoted the presence of ice crystals. The number of small particles found on the samples taken shortly after seeding was significant. This immediate change in the size distribution of particles is indicative of the large concentration of minute ice crystals caused by the cold dry ice. In a relatively short time, however, the ice crystals grew to millimeter dimensions, as evidenced by the snowfall observed on the ground a half hour after seeding. During one experiment with an overcast cloud layer about 1000 feet thick, the visibility measured at the ground was reduced for sev-

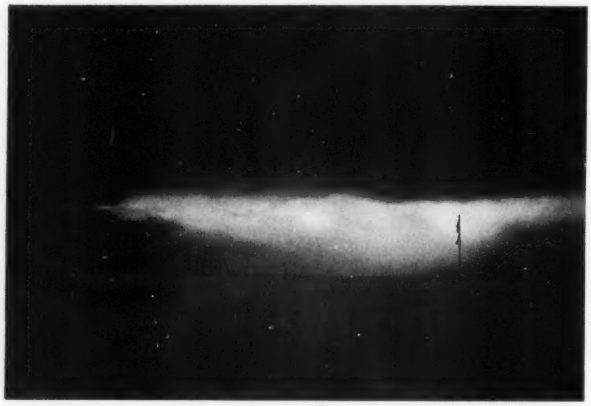


FIG. 3 — **Line of clearing produced by dry ice seeding from aircraft.**

FIG. 4 — Supercooled cloud begins to crystallize as baskets of dry ice, spaced along the blimp's tethering line, are raised into the overcast.

eral minutes from many miles to less than one-quarter mile by the seeding-induced snow.

The dissipation of supercooled clouds by seeding with dry ice from an airplane, thus was found to be effective in Greenland; clear areas ten square miles in extent were readily produced in the overcast with only 15-20 pounds of crushed dry ice.

Blimp Employed

A technique simpler than aircraft seeding was found to be equally effective in creating holes in thin low clouds. Plastic mesh (berry) baskets containing crushed dry ice were attached to the tethering line of a blimp at 25-foot intervals.

On two occasions, with stratus ceilings of 700 and 1200 feet and winds of one to three knots, ten baskets of dry ice (1 pound per basket) were raised into the overcast. As the cloud moved through the baskets, seeding was accomplished effectively. Plumes of ice crystals were observed from the ground extending as far as 100 yards downwind of the baskets (Fig. 4). The ice crystals continued to increase at the expense of the supercooled cloud droplets so that after some 30 minutes, at a downstream distance of one and one-half to two miles, the crystals grew large enough and snowfall commenced. A clearing line up to one-half mile wide resulted. The seeding-process continued for about an hour — the time required for the dry ice in the berry baskets to dissipate. The generated break was observed for at least two hours before it moved out of sight.

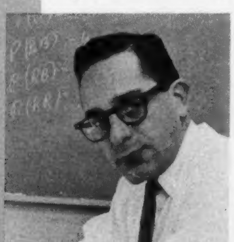
This seeding technique, employed on a large scale, offers a simple but reliable method for keeping an airstrip open during suitable overcast-type whiteouts and fog whiteouts. Blimps, mounted on mobile sleds, could be placed an appropriate distance upwind from camp so that breaks in a whiteout would be created over the airstrip. By spacing two or more seeding blimps perpendicular to the wind direction, the width of the cleared area could be controlled.

The Whiteout investigation demonstrated that under appropriate meteorological conditions, cloud modification techniques can be applied successfully to aid military missions in the arctic. Clear areas in thin supercooled clouds and fog can be produced at ice cap outposts in support of air operations. As little as five pounds per mile of dry ice dispersed from aircraft, or ten pounds suspended from tethered balloons, produced clear areas of several square miles.

MURRAY E. KAMRASS, author of "Aircraft and Combat Mobility" was project engineer on the recent Mobile Army Transport Study (MAT) conducted by the Laboratory for the Army's chief of Research and Development, and is currently responsible for the Fire Suppression Technology Study (FIST) sponsored by the Army's Transportation Corps. He was also project engineer on the transonic and supersonic bomb separation program.

Head of the Systems Operation Section of CAL's Operations Research Department, Mr. Kamrass' experience includes research in the fields of compressible flow aerodynamics, acoustics and industrial airflow problems as well as systems analysis.

He received his B.S. in Aeronautical Engineering from the University of Michigan and an M.S. in Mechanical Engineering from the University of Buffalo.



Before joining the Laboratory, Mr. Kamrass worked as an aerodynamicist for the Stinson Division of Convair.

He is secretary of the Niagara Frontier Section, Institute of the Aerospace Sciences.

Research Physicist JAMES E. JIUSTO, coauthor of "Seeding Whiteouts in Greenland," is a member of the Laboratory's Atmospheric Physics Section of the Applied Physics Department where he specializes in such problems as cloud physics, weather modification, systems meteorology, climatology and weather radar.

While serving as a weather officer with the Air Force, Mr. Jiusto completed a graduate program in meteorology at the Massachusetts Institute of Technology. He holds a bachelor's degree in Mathematics and Physics from the New York State College for Teachers at Albany, and a master's degree in school administration.

He is a member of the Royal Meteorological Society (London) and the American Meteorological Society.

No stranger to arctic climes is RODDY R. ROGERS, an Associate Physicist at the Laboratory and a member of the atmospheric physics "team." Mr. Rogers, in company with his coauthor, spent the better part of last summer seeding clouds on the Greenland ice cap.

Before joining the Laboratory two years ago, Mr. Rogers worked as research assistant with New York University and with Massachusetts Institute of Technology.

He holds degrees in meteorology from The University of Texas and M.I.T.; his specialties are radar and turbulence.

During 1957 and 1958 Mr. Rogers served with the predecessor to NASA, the National Advisory Committee for Aeronautics at Langley Field, Virginia.

He is a member of the American Meteorological Society.

The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited, and those marked with an asterisk may be distributed only within the United States. Please direct your request to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"INVESTIGATION OF HELICOPTER ROTOR BLADE FLUTTER AND FLAPWISE BENDING RESPONSE IN HOVERING," DuWaldt, Frank A., Gates, Charles A., Piziali, Raymond A.; CAL Report No. SB-1168-S-1; August 1959; 146 pages.*

Experimental flutter and response data were obtained using a model helicopter rotor blade in the hovering condition and these data were compared with results obtained from theoretical calculations. A literature survey of rotor downwash theory and measurement techniques was made and an outline of an experimental program formulated which would furnish rotor downwash distribution and blade loading data.

"STUDY TO DETERMINE AN ACCIDENT RESEARCH METHODOLOGY," Jagger, Douglas; CAL Report No. VJ-1378-V-1; July 1960; 39 pages.

A study to determine an appropriate accident research methodology has resulted in a method designed to define and assess the variables present in the Driver-Vehicle-Highway-Environment Complex, with respect to their importance in producing, or contributing to highway accidents. The proposed method provides for simulation of the overall traffic flow pattern in terms of analytical sub-models, each constructed to represent one category of potential accident.

"PRELIMINARY ANALYSIS OF ROAD LOADING MECHANICS," Fabian, Gardner, J., Clark, Daniel C., Hutchinson, Charles H.; Presented at the Highway Research Board, 39th Annual Meeting, Washington, D. C.; January 12, 1960; 27 pages.

A program for the development of a dynamic theory of road-vehicle systems is outlined. An analysis is presented of the basic problems involved in the development of a comprehensive treatment of road loading mechanics. The complete road loading system is defined and its various elements are discussed. The development of a simple but realistic mathematical model of the vehicle as the road-loading element is accomplished.

"AN ANALYSIS OF RADAR CROSS SECTION MEASUREMENT TECHNIQUES," Melling, William P.; CAL Report No. UB-1088-P-104; September 1959; 23 pages.

Radar Cross Section is conveniently determined using a high frequency radar to observe the return from a scale model of the target. Through choice of the scale factor it is possible to utilize a test radar of convenient transmission frequency for the derivation of the radar cross section that would be observed by an operational radar of any given frequency.

"AN ANALYTICAL INVESTIGATION OF AIRPORT CAPACITY," Blumstein, Alfred; CAL Report No. TA-1358-G-1; June 1960; 258 pages.

The problems of air traffic control, particularly those of capacity in the terminal area, are examined indicating the need for increased airport capacity. Analytical models are formulated expressing the capacity of an airport runway as a function of parameters characterizing the airport, the air traffic control system, and the arriving aircraft.

"MEASURED TRANSITION PROBABILITIES FOR THE SCHUMMAN-RUNGE SYSTEM OF OXYGEN," Treanor, Charles E., Wurster, Walter H.; Reprinted from the Journal of Chemical Physics, Vol. 32, No. 3; pp. 758-766; March 1960; 9 pages.

Transition probabilities for the Schumann-Runge system of O_2 have been measured in absorption in the wavelength region 2650-3900 A. Oxygen was heated in a shock tube to temperatures up to 4500° K, thereby populating high vibrational and rotational levels. Absorption spectra were photographed using a high-speed flash lamp and a large Littrow quartz spectrograph.

"THIN-FILM THERMOMETER MEASUREMENTS IN PARTIALLY IONIZED SHOCK-TUBE FLOWS," Marrone, P. V., Hartunian, R. A.; Reprinted from The Physics of Fluids, Vol. 2, No. 6; November-December, 1959; 2 pages.

In a recent experimental shock-tube study of the processes of boundary-layer transition and heat transfer at high temperatures, conducted with thin-film resistance thermometers, it was found that the presence of even very small degrees of ionization in the shocked gas was sufficient to induce spurious electrical signals in the output of the thin-film gauge. This paper discusses the techniques employed in overcoming this difficulty.

"PASSAGE OF SHOCK WAVES THROUGH DUCTS OF VARIABLE CROSS SECTION," Rudinger, George; Reprinted from The Physics of Fluids, Vol. 3, No. 3; May-June 1960; 6 pages.

A variety of wave patterns are found to result from shock-wave produced supersonic flow passing through a duct of variable cross section, the shape of which is approximated by a single discontinuous area change. Examination of the transient processes that precede the establishment of the final flow shows that only one of these solutions can actually be realized if the duct converges monotonically. Other solutions may be found for more general duct configurations, but the correct wave pattern may need to be established with the aid of a wave diagram in which area changes are considered.

"IN-FLIGHT SIMULATION OF RE-ENTRY VEHICLE HANDLING QUALITIES," Harper, Robert P., Jr.; Paper No. 60-93 presented at the IAS National Summer Meeting, Los Angeles, California; July 1960; 31 pages.

The work reported in this paper summarizes the results of the first phase of a comprehensive flight research program whose aim it is to increase knowledge in flight control and handling qualities. The aims include the re-evaluation of parameters examined by earlier investigations in the light of the new missions and tasks, and the exploration of parameters not normally considered in assessing the performance of the pilot-vehicle combination.

"A THEORY OF WING-PROPULSION COMBINATIONS IN SLOW FLIGHT," Vidal, Robert J.; CAL Report No. AI-1190-A-1; September 1959; 36 pages.*

The development of a theory treating wing-propulsion systems in slow flight is presented. This development is applied to a class of configurations, characterized by wing and propulsion wakes which are equal in span, and is used to predict the performance of this class of aircraft.

CORRECTION

The definition of antenna gain in the radar equation in the Winter 1961 edition of Research Trends, Volume VIII, No. 4, page 4 should have read $4\pi A/\lambda^2$